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Unpacking the RFID Investment Decision

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Abstract

Mandates aside, there are many reasons why firms decide to move forward with or delay investment in RFID technology. In this paper we use a theoretically based, easy to implement methodology to empirically derive a relative importance scale of those factors that influence the decision to invest in RFID technology. More specifically, we compare the factors that matter most and least to a sample of firms that have adopted RFID technology with a sample of firms that have yet to embrace RFID technology. The theoretical and practical implications are that both RFID adopters and non adopters are driven by the promise of greater data accuracy, improved information visibility, service quality, process innovation, and track and trace capabilities. What separates the adopters from the non adopters is an opportunity to derive strategic benefits from RFID through improved decision making. Not surprisingly, the non adopting firms are primarily concerned with the high acquisition and other ongoing costs associated with RFID technology.

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CONTRIBUTED PAPER

Unpacking the RFID Investment Decision

A recent study dealing with RFID investment decisions finds that while adoption cost is a primary concern, a key factor is the opportunity for strategic benefits.

By Byron W. Keating, Tim R. Coltman, Samuel Fosso-Wamba, and Valerie Baker

ABSTRACT | Mandates aside, there are many reasons why firms decide to move forward with or delay investment in radio-frequency identification (RFID) technology. In this paper, we use a theoretically-based, easy to implement methodology to empirically derive a relative importance scale of those factors that influence the decision to invest in RFID technology. More specifically, we compare the factors that matter most and least to a sample of firms that have adopted RFID technology with a sample of firms that have yet to embrace RFID technology. The theoretical and practical implications are that both RFID adopters and nonadopters are driven by the promise of greater data accuracy, improved information visibility, service quality, process innovation, and track-and-trace capabilities. What separates the adopters from the nonadopters is an opportunity to derive strategic benefits from RFID through improved decision making. Not surprisingly, the nonadopting firms are primarily concerned with the high acquisition and other ongoing costs associated with RFID technology.

KEYWORDS | Information technology; innovation; radio-frequency identification (RFID); technology adoption

I. INTRODUCTION

Technology innovation is widely recognized as an important driver of business transformation and economic growth [1], [2]. The most radical examples are found in situations where the creation and application of information technologies provide open and ubiquitous connectivity. The personal computer, mobile telephone, and internet are examples of information technologies that have become both ubiquitous [3] and disruptive [4]. Radio-frequency identification (RFID) represents a new technological innovation that has captured the imagination of the scholarly community and some scholars have gone so far as to suggest that RFID represents a disruptive innovation [5] that will revolutionize the supply chain [6].

History tells us that the path to acceptance within the business community can be long for technological innovations. For example, the internet has its origins in the late 1960s and 1970s, and did not reach wide acceptance until the late 1990s. The primary catalyst for widespread adoption came with a change in the business perceptions of value based on the advent of fast, reliable, and low-cost hypertext markup language applications. In other words, the perceived benefits or risks that are held by the users of each technological innovation influence the rate of acceptance [7], [8].

It is critical, therefore, that the perceptions of business value—that are held by adopters and nonadopters—be identified and brought into the early discussions about RFID innovation. This is necessary to spur a deeper understanding of exactly what factors should be addressed to drive forward the development of RFID. Although pundits have predicted high rates of RFID adoption, the reality is that many firms have yet to seriously embrace RFID technology. The reluctance by many of Wal-Mart's retail suppliers to comply with its RFID mandate is a high-profile example. This implies that not all firms are willing to embrace RFID and the technology may not be as disruptive as some have made it out to be.

To shed light on the diffusion of RFID, we unpack the RFID investment decision to identify the relative importance of specific drivers and impediments. The study draws upon a global sample of 133 senior information technology (IT) and supply-chain managers from a diverse range of

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firms that have either adopted RFID, or are currently considering investment in RFID. To guide this work, we propose two research questions.

1) What factors matter most and least to firms when considering an investment in RFID?
2) How does the importance of these factors vary between adopters and nonadopters?

These questions are of practical and theoretical importance and directly address the call in this special issue for a greater understanding of the business impact from RFID innovation. First, much has been written about the implications of RFID as an alternative to traditional automatic identification and data capture technologies such as barcode systems for tracking items throughout the supply chain [9]. Anecdotal evidence indicates that RFID has had a relatively slow rate of adoption and that the widespread RFID adoption based on a solid business case is still some years away. The main reason for this is that RFID technology provides a particular challenge when it comes to understanding the way firms assess business value and risk. For example, the benefits of RFID technology are greatest when it is integrated into a wider interorganizational context [10], [11]. This is common to prior work that has found that the diffusion of interorganizational innovation is dependent upon network externalities and positive feedback [12], [13].

Second, prior work on RFID diffusion has developed a laundry list of possible factors that contribute to the RFID business case. These include unique item and product level identification, non-line-of-sight requirements, multiple tag and item reading, greater data storage capacity and data read/write capabilities [14], [15], better inventory records [16], improved organization coordination and control [17], real-time data collection and sharing among supply chain stakeholders [18], and business process innovation [19]. However, these benefits come with potential risks such as: high infrastructure and implementation costs [20], [21], switching costs [21], immature standards, and privacy and security concerns [20]. The studies described are common in that they characterize RFID according to discrete benefits and risks. Little work has compared the relative importance of a large number of different benefits and risks or tested the moderating effects (individual and organizational) that may influence the relative importance of various factors on the rate of RFID diffusion and adoption.

Third, known theoretical and methodological biases have impeded progress. These biases include the pro-innovation bias (all adoption is good), rational bias (adopters make rational decisions) [22], and pro-adopter bias (nonadopters are understudied) [8]. What we require is a method that allows us to capture the relative importance of different RFID benefits and risks in a realistic way. We utilize a novel method based on maximum difference scaling, or best- worst scaling, to identify the organizational factors considered to be most important and least important to the RFID investment decision. The method has been successfully applied to many different organizational contexts in order to identify the efficacy of managerial decision making, and to identify the preference structures for products and services [23].

The remaining sections of this paper are organized as follows. The next section develops the theoretical background as it applies to the IT innovation literature and the specific benefits and risks associated with RFID technology. We then describe the methodology and present the results from our survey of 133 firms. Finally, we conclude with a discussion on the implications of this work for academics and practitioners.

II. BACKGROUND THEORY

A. The IT Innovation Literature

Although the IT innovation literature is both voluminous and diverse, researchers have characterized the literature according to two broad streams of work: 1) structural characteristics of industrial innovation and 2) the nature of innovation demand. The first stream deals with the different types of innovation and has examined the structural characteristics of an industry, product (architecture), market, or firm. The primary focus is to seek answers to why and how IT artifacts emerge and what impact they have on the business. The second stream has focused on modeling the demand for innovation and has primarily applied diffusion of innovation theory to discern patterns of adoption for new artifacts [8]. In this stream of research, scholars have sought to identify adopter attitudes and their innovation-related behavior [24]. This has led to the identification of various innovation characteristics, technologies, and organizational and environmental factors that affect the IT adoption decision [25].

For example, the seminal work by Rogers [8] has proposed that the following characteristics explain a firm's usage of particular innovations: 1) the degree to which an innovation can bring benefits to an organization; 2) the degree to which an innovation is consistent with existing business processes, practices and value systems; 3) the degree to which an innovation is difficult to use; and 4) the degree to which the results of an innovation are visible to others. Understanding the impact of each of these characteristics is the key to IT innovation success.

Despite increased awareness of the characteristics that underpin IT innovation, many organizations still report an inability to justify their investment decisions in new IT. This is a demand side problem that arises due to a lack of understanding about the nature of the costs and benefits associated with the adoption and use of IT [26, p. 38]. In other words, widespread adoption of RFID will continue to stall until managers with responsibility for adoption decisions can articulate the real business value of RFID within their organization. This requires a sound understanding of the various drivers and impediments (benefits,

risks, challenges, costs) to RFID and should precede the commitment of large amounts of money, time, and resources towards RFID technology.

The strategic management literature suggests that the categories of opportunity (benefit) and threat (risk) are relevant and consequential for decision processes [27]. In the specific case of RFID technology, we can derive that the organizational benefits achievable through RFID adoption present as opportunities and the potential adoption risks are categorized as threats [28]. The literature on managerial decision making identifies opportunities as a positive situation in which gain is likely; alternatively, threats are seen as a negative situation in which loss is likely [29].

B. Specific Factors Influencing Adoption of RFID

RFID technology offers a vast range of benefits. For example, RFID technology can help all stakeholders to reduce shrinkage, reduce material handling costs, increase data accuracy, and enable supply chain business process innovation and improved information sharing [19], [30]–[32].

An important part of the strategic decision-making process is to weigh up the benefits of adopting RFID against the risks. The relatively low rates of adoption imply that within the minds of managers, the risks of RFID adoption may outweigh the benefits. The risks associated with RFID range from organizational factors, such as adequate infrastructure, resources, and skill [33] to technical factors that are centered around systems integration [34]. The high costs of purchasing tags and supporting infrastructure are thought to be a prominent adoption barrier. Sigala [35, p. 24], in the study on the RFID implementation issues, practices, and benefits within the foodservice sector, found that the two most important issues that needed to be addressed before committing to RFID were: 1) the RFID cost-benefit analysis; and 2) the better way to integrate RFID system with existing business models, business strategies, staff operations, and technology infrastructure. On the other hand, Hellström [36], in an RFID trial at IKEA, found that the cost of introducing RFID technology is not generally a barrier. This implies that capital costs are not the only risk to be considered to RFID adoption. Many technical challenges arise such as the integration of RFID tags and readers with supporting software and existing IT infrastructure.

The standardization of data across the supply chain, such as data related to products, vendors, and shippers, as well as the data on the RFID tags themselves, is critical in order to realize real business value from RFID [37]. In fact, Whitaker *et al.* [34] empirically determined that a lack of industry RFID standards negatively affected adoption of the technology. Their research results suggested that standards ambiguity may limit the expectation of return on investment (ROI) because of the inability of firms to deploy RFID across supply chain partners.

Part of the attractiveness of RFID is the ability to create more transparent information sharing across the supply chain. However, for firms to achieve any real planning benefits from RFID adoption, they need to deal with the complexity of information sharing across multiple partners. Marley and Louviere [38] suggest that the biggest advantages in this area will be for those firms operating in complex manufacturing industries that receive a widespread variety of goods on a frequent basis. For firms operating within commodity markets, RFID is likely to provide less of an advantage. The implications that can be drawn are that the strategic benefits from RFID are context dependent and may differ between various firms based on individual and organizational factors.

III. DESCRIPTION OF THE METHOD

A. Experimental Research Design

An effective method for evaluating the relative importance of the benefits and risks involved in an RFID investment is to model the actual tradeoff that managers are willing to make. We utilize a reduced form of discrete choice analysis referred to as best–worst scaling [38], [39]. The method is based on an ordering task that requires respondents to make a selection from a group of factors by choosing the "best" (most preferred) and "worst" (least preferred) factor from a series of blocks that contain three or more factors. The factors could be attributes of a product, options in a decision, or bundles of services and products. Specifically, best–worst scaling assumes that there is some underlying subjective dimension, such as "degree of importance," "extent of preference," "degree of concern," etc., and that the researcher wishes to measure the location or position of some factor on that dimension. The approach is particularly effective in ordering preferences when the number of factors is large, as individuals are better able to determine which two factors from a smaller group of items are "best" and "worst" than they are at providing the specific ordering of $1, 2, 3, \ldots, N$. Best–worst scaling has the added benefit that it is quick and simple to execute, provides results that are empirically consistent with more complex ordering tasks, and is theoretically in line with the precepts of random utility theory.

The statistical model that is used for estimation is the conditional logit model [40]. This model was proposed by Nobel Laureate Daniel McFadden as an extension to the multinomial logit model which allows for the inclusion of explanatory variables related to the choice set options. These choice set options (i.e., which attribute appears in which block) are determined according to some underlying experimental design. In the case of best–worst choice models, this is achieved using a balanced and incomplete block design (BIBD).

This type of design aims to minimize the resulting number of choices, while ensuring balance between the

total number of times a factor appears in the experiment, and the number of times each factor appears alongside every other factor in the design [42].

In this study, we utilized a 21-factor design, resulting in 21 choice sets of five factors that were evaluated by every respondent. A detailed pretesting procedure was employed to capture the full range of factors that are potentially important in the RFID investment decision. This list of factors was sourced from extensive rounds of exploratory work that included reviewing the academic literature, industry reports, and websites, along with insight gained from numerous discussions with experienced academics, customers, and practitioners. This work identified 21 factors in four general categories that reflect the common themes in the literature related to the evaluation and decision to invest in RFID. These were: 1) resource issues: acquisition costs [20], [21], ongoing costs [26], [35], top management commitment [8], operational level expertise [33], replacement costs [30], [31], and integration complexity [34]; 2) technology issues: standards ambiguity [20], [37], security threats [20], technology maturity [22], and privacy threats [20]; 3) automation issues: inventory management [16], data capacity [14], [15], track and trace [17], compliance [18], and process innovation [19]; and 4) supply chain issues: information visibility [17], [37], data accuracy [15], service quality [20], decision making [7], [8], competitive differentiation [45], and technology leadership [45]. Operational definitions were developed to capture the domain for each of the 21 factors and to ensure that each responding decision maker understood the meaning of these factors in exactly the same way. The definitions of these factors are available upon request.

Pilot testing conducted during a recent research forum on RFID held by the Wireless Internet for Mobile Enterprise Consortium at the University of California Los Angeles (UCLA) confirmed the validity of the list along with their definitions. This pilot testing was conducted in two phases. The first phase involved a brief presentation on the purpose of the research. Following this presentation, a small group of 14 academics and practitioners was requested to read through the list of attributes and to comment on the completeness of this list, and the associated definitions. The industry respondents were representative of the population of firms having previously adopted or actively considering and RFID investment decision. The pilot sample represented a broad cross section of viewpoints, with firms of different sizes, industries and at different stages of technological maturity, and different levels of RFID adoption ranging from non to extensively integrated solutions. The academics were also well acquainted with the nature and benefits of RFID.

The second phase of the pilot testing required respondents to complete a paper version of the survey. Respondents were asked to comment on the readability, layout, and length of the questionnaire. While a small number of changes to the phrasing of definitions was required, the overall responses from our pilot testing supported the developmental work and methodological approach undertaken. Moreover, participants commented on the exhaustiveness of the factor list, and while no additional factors were suggested, we did note that the relevance of certain factors differed greatly across respondents.

While we are confident that this list is representative of the factors influencing the RFID adoption decision, we acknowledge that it is not exhaustive, and that there may be other factors influencing the decision to invest in RFID that have not been included in our study.

In addition to the experimental best–worst task, respondents were also asked questions about their risk orientation, and the dependence of the firm on technology. The specific questions along with the psychometric properties of the associated measurement scales are available upon request.

B. Data Collection Procedures

Responses were sampled randomly from the readership of the *RFID Journal*. One hundred and thirty three readers of *RFID Journal* responded to our e-mail invitation and completed the online version of the questionnaire. The e-mail invitation contained information on the study and a link to the survey url. The survey had an average completion time of 30 min and was divided into three parts. The first part asked for contextual information on the firm and its prior experiences with emerging technologies such as RFID. The middle section presented respondents with the 21 choice tasks. These tasks were stacked according to a BIBD which ensures that each attribute appears the same number of times as every other attribute, and that it appears with every other attribute at least once. The key advantage of this design approach is that it minimizes both the cognitive burden on respondents and the generalized variance of the resulting parameter estimates. While prior experience with best–worst scaling reveals no statistically significant differences in response profiles when tasks are presented in a block versus separately, the block approach does have some advantages in terms of completion rates (i.e., less respondents exit the survey prematurely). The final section captures information on the characteristics of the individual respondents. Relevant data from the first and last part of the survey are discussed below.

The distribution of respondents covers most of the main segments of business activity: wholesale trade (5%), retail trade (7%), transportation and communications (10%), business services (31%), communication services (6%), manufacturing (29%), finance and insurance (3%), mining (3%), and government administration and defense (5%). Firm size was also well distributed, with 39% of the sample from small sized firms (less than 20 employees), 21% from medium sized firms (20–200 employees), and 40% large firms (more than 200 employees). The mean number of employees for the entire sample was 53 188.

The results indicate that our sample is skewed towards larger firms. A review of the sample indicates that the majority of these firms are subsidiaries of multinational companies. Key descriptive sample data are provided in Table 1.

To test for nonresponse bias, a comparison was made between early and late respondents across a range of questions [50]. The findings revealed that nonresponse bias was not an issue.

IV. EVALUATING THE TRADEOFFS BETWEEN FACTORS

A. Aggregate Model

In this section, we present the findings from the best–worst scaling. For the purpose of this analysis, we used a variant on best–worst that focused on most–least. That is, we asked respondents to identify from the set of possible alternatives which factor mattered "most" and "least" in terms of the RFID investment decision. This is a common variation of the method [38], [48].

Table 1 Firm Characteristics

	Aggregate (N=133)	*Adopter (N=57)*	*Non-adopter (N=76)*
Industry			
Agriculture and Fishing	2.5	5.9	0.1
Construction	4.2	3.9	4.4
Finance, Insurance and Real Estate	3.4	0.1	5.9
Manufacturing	29.4	25.4	32.3
Mining	2.5	5.9	0.1
Public Administration	5.0	3.9	5.9
Retail Trade	6.7	7.8	5.9
Services	31.1	31.4	30.8
Transport, Communications Electric	10.1	11.8	8.8
Wholesale Trade	5.0	3.9	5.9
Firm size			
Small business (less than 20 staff)	39.3	30.1	47.2
Medium (20 to 200 staff)	21.2	30.0	13.2
Large (more than 200 staff)	39.5	39.0	39.6
Mean	53,188	83,950	3,780
Financial position			
Revenue (Average $US,000)	2,614,463	4,519,776	928,993
Profit margin (average)	17.5	15.1	19.6
Existing infrastructure			
Enterprise resource planning	53.9	46.4	59.5
Supply chain management	57.7	55.4	59.5
Customer relationship management	84.6	89.3	81.1
Internal Database	62.3	57.1	66.2
Business intelligence/Data warehouse	68.5	67.9	68.9
Internet applications/Web services	70.0	69.6	70.3
Product lifecycle management	69.2	76.8	63.5

Table 2 provides a summary of the key data from this analysis. There are two types of descriptive statistics represented in this table. The first are derived from actual counts. As the appearance of each attribute is controlled by an experimental design (BIBD), and everyone who completed the survey saw exactly the same choice sets, it is possible to estimate a simple best–worst score by subtracting the total number of times an attribute is selected as "worst" from the total number of times the attribute is selected "best." Marley and Louviere [38] demonstrate that this score is almost perfectly correlated with the coefficients derived from a conditional logit model. The column labeled "*B*" provides the corresponding unstandardized coefficients for the conditional logit model [39].

Analogous to simple linear regression, the unstandardized figures are model specific, and provide an estimate for the importance of one factor relative to another. For ease of interpretation, we rescale these values in the "share" column according to the underlying logit model such that they sum to 1. We divide the exponential of a particular "*B*" parameter by the sum of the exponentials of all the parameter coefficients in the particular model to obtain the share values. From this transformation, we can see that the factor with the greatest influence on RFID investment is "data accuracy" which accounts for 11% of preferences, followed by "top management commitment" and "information visibility" which account for 8% each. Conversely, the factors with the least impact on the RFID investment decision are "privacy threats" followed by "security threats" and "standards ambiguity" which account for 1%, 2%, and 2%, respectively.

A valuable byproduct of the relative nature of choice-based modeling is that the resulting factor effects are captured on a common scale. In other words, "top management commitment" with a relative share of 8% is actually twice as important as "integration complexity" with a relative share of 4%, and eight times as important as "privacy threats."

Our findings imply that many of the espoused advantages and challenges associated with the use and adoption of RFID are actually not that important when managers are forced to trade off between competing priorities. Concerns associated with security and privacy, data capacity, systems integration, and universal standards diminish when evaluated alongside competitive and operational drivers. In this way, our research provides a valuable extension to prior research that has sought to uncover the drivers of RFID investment, without attempting to evaluate the relative importance of these drivers. One of the real advantages of the method is that it exposes the latent preferences that only emerge when decision makers have to choose between how they allocate scarce resources. Thus, our method is superior to traditional scaling techniques because it reflects the decision-making realities that are common in day-to-day management.

Table 2 Best–Worst Results for Aggregate Model

	Best	*Worst*	*B-W*	*B*	*Exp(B)*	*Share*
Data accuracy	248	32	216	0.98***	2.66	0.11
Top management commitment	245	89	156	0.68***	1.97	0.08
Information visibility	199	61	138	0.63***	1.87	0.08
Inventory management	214	79	135	0.62***	1.85	0.08
Track & trace	193	70	123	0.56***	1.74	0.07
Service quality	135	51	84	0.41***	1.50	0.06
Process innovation	163	81	82	0.37***	1.45	0.06
Acquisition costs	174	98	76	0.33***	1.39	0.06
Ongoing costs	168	101	67	0.29***	1.34	0.05
Decision making	123	80	43	0.21***	1.24	0.05
Integration complexity	121	105	16	0.08	1.08	0.04
Operational level expertise	122	113	9	0.05	1.05	0.04
Technological maturity	115	119	-4	-0.03	0.97	0.04
Competitive differentiation	153	174	-21	-0.15	0.86	0.03
Technology leadership	100	154	-54	-0.26	0.77	0.03
Replacement costs	78	160	-82	-0.34	0.71	0.03
Compliance	61	183	-122	-0.52	0.59	0.02
Data capacity	46	201	-155	-0.67	0.51	0.02
Standards ambiguity	39	228	-189	-0.85	0.43	0.02
Security threats	56	254	-198	-0.92	0.40	0.02
Privacy threats	40	360	-320	-1.47	0.23	0.01

Note: *** p<0.001 ** p<0.01 * p<0.05.

B. Distinguishing Between Adopters and Nonadopters

While the data presented above provide an interesting snapshot of what influences RFID investment at the aggregate level, it is also valuable to understand how these preferences vary between adopters and nonadopters. However, it is not possible to make a direct comparison between unstandardized coefficients for two different conditional logit models without first isolating the influence of the scale factor (i.e., variance). To correct for this, we determined an appropriate multiplier for the nonadopter model relative to the adopter model using the procedure suggested by [43]. Table 3 presents the corrected coefficients for the adopter and nonadopter samples. Fig. 1 presents a graph of the rescaled coefficients based on the logit-based transformation described above. The advantage of Fig. 1 is that it provides a quick visual representation of how preferences differ across the two groups on a common scale. Caution needs to be employed, however, as this figure does not indicate whether these differences are statistically significant.

To address this issue of statistical significance, we used a two-step process that first considers those factors that are significant within each respective model, before considering which factors are also significantly different between the models. The first step reveals that there are eight factors that are statistically significant to the adopter sample, and ten factors that are statistically significant to the nonadopter sample. The three most important factors to the adopter sample were "data accuracy" followed by "top management commitment" and "information visibility." Although "data accuracy" is also the most important factor for the nonadopter sample, the second and third most important factors were "inventory management" followed by "track and trace," respectively. It is noteworthy that all of the factors identified as important at the aggregate level were still significant when we drilled down to the adopter and nonadopter samples. The only notable difference was that the nonadopter sample also identified "acquisition costs" and "ongoing costs" as significant. The second step in our analysis required that we compare the coefficients across the models. Because of the scale factor correction employed, we can directly compare the magnitude of the coefficients in the adopter and nonadopter models.

The results indicate that "decision making," "information visibility," "process innovation," "service quality," and "top management commitment" are perceived as universally important to both groups of respondents. T-tests confirmed that the differences were small in magnitude and not significant at the 95% confidence level. Our findings concur with the recent

Table 3 Adopters and Nonadopters

	Adopt (B)	*Non-adopt (B)*	Sig.
Acquisition costs	0.12	0.65***	***
Competitive differentiation	0.19	-0.52	(***)
Compliance	-0.43	-0.78	(*)
Data accuracy	0.97***	1.30***	
Data capacity	-0.82	-0.73	
Decision making	0.25**	0.23**	
Information visibility	0.83***	0.64***	
Integration complexity	0.02	0.16	
Inventory management	0.47***	0.95***	**
Ongoing costs	0.20	0.47***	*
Operational level expertise	0.17	-0.05	
Privacy threats	-1.77	-1.64	
Process innovation	0.39***	0.47***	
Replacement costs	-0.60	-0.20	(**)
Security threats	-1.14	-1.01	
Service quality	0.50***	0.44***	
Standards ambiguity	-0.78	-1.20	(**)
Technological maturity	0.21	-0.25	(**)
Technology leadership	-0.09	-0.49	(*)
Top management commitment	0.84***	0.75***	
Track & trace	0.47***	0.81***	*

Note: *** p<0.001 ** p<0.01 * p<0.05.
Significance figures in brackets relate to differences in non-significant attributes.

work of [45], which shows that the adoption and continued use of new technologies is strongly influenced by competitive pressures and operational efficiency.

Drawing on the work of [46], the results suggest that these factors can be considered *order losers*, and that serious deficiencies in these areas would influence future adoption, as well as the continued use, of RFID. The two cost-related factors and data accuracy and track and trace, on the other hand, can be interpreted as *order winners* for the nonadopters. These factors were significantly different across the two models, representing hurdles that must be overcome in order to convince a firm to adopt RFID. This suggests that there is still work to be done to build the basic business case for RFID in the minds of nonadopters. The remaining 11 factors did not have a significant influence on the use or adoption of RFID. Extending this framework, these factors can be considered *order qualifiers*. That is, they are factors that are often required to meet market expectations and for vendors to remain competitive, but they are not critical to the investment decision.

V. CONCLUSION

This research makes two specific contributions. The first contribution is an improved understanding for researchers and managers of the perceptions of RFID issues, and the extent to which these perceptions differ between adopter and nonadopter firms. The second contribution was to provide an illustration for researchers of how the best–worst scaling method can be used to identify the relative importance of a set of factors influencing choice, selection, or adoption of a new technology.

The method used here has some distinct advantages over traditional scaling methods that are subject to measurement bias, and do not evaluate perceptions on a common scale. Specifically, the best–worst scaling method enabled us to develop a common scale that could be used to compare the relative importance of 21 factors across different models. The results clearly show that ten factors are particularly important and statistically significant to perceptions of RFID technology.

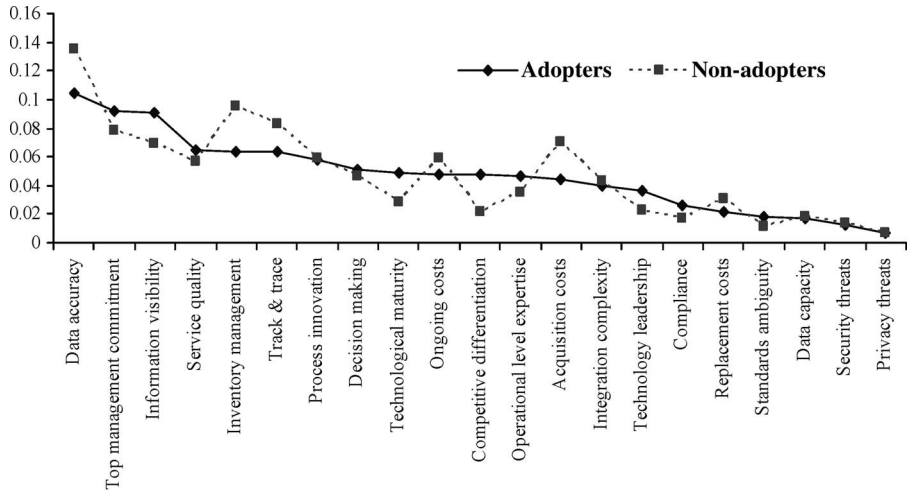

Fig. 1. ***Share of preferences for adopters and nonadopters.***

The findings of our study suggest that the uptake of RFID is dependent upon the strategic decision-making benefits of improved data accuracy, information visibility, process innovation, and service quality. Concomitant to realizing these benefits is the commitment of top management. This has direct implications for managers as it requires that RFID investments are strategically aligned with the firm's operational capabilities. Although nonadopters are also interested in these benefits, they remain concerned with the costs of implementation and the impact on inventory management and track-and-trace capabilities.

The main limitation of this type of study is the assumption that the factors included in the experimental task represent the primary factors influencing the choice outcome. While we took care to review the key literature, and to consult with industry and academic experts in the area of RFID, there is always the possibility that we missed something.

Future work should build on this study by seeking to reaffirm these results. It may also be interesting to understand how organization constraints influence the findings. For instance, it is likely that cost concerns will differ depending on an organization's risk profile [47]. Likewise, it is also probable that the technological orientation of a firm and prior experience with innovative technologies may also provide useful insights into the RFID adoption decision [48]. We would recommend that future research take up these issues. Further, as investments in technologies such as RFID inevitably involve collaboration across internal disciplinary boundaries, and with external suppliers and supply chain partners, we suggest that future research would benefit from exploring how preferences for RFID features vary between these different stakeholders. In line with the strategic IT alignment research tradition, it would also be interesting to understand how different degrees of preference alignment influence and affect organizational performance. The case of Wal-Mart is a good example of how misalignment between stakeholder interests can influence RFID implementation. Key drivers of Wal-Mart's RFID mandate for its top 100 suppliers were increased efficiency, improved communication, and better inventory management. Yet, for suppliers, the capabilities of RFID were much less important than the cost of compliance. Though the majority of the suppliers did comply in the end (95%), they took a low-cost, minimalist approach to deployment, using in-house resources, and ignoring systems integration [49]. Wal-Mart has now adopted a more conciliatory approach and is working with its second tier suppliers to better understand their needs in an effort to unlock the potential of RFID.[1] ■

[1]Due to space constraints, details on the psychometric properties of the scales and the definitions of the factors used within the study have been omitted. Please email the first named author for this information.

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